

Baryonic Density from Primordial Li

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Abstract. Lithium abundances in a selected sample of halo stars have been revised by using new accurate T_{eff} . From 41 plateau stars we found no evidence for intrinsic dispersion, a tiny trend with T_{eff} and no trend with $[\text{Fe}/\text{H}]$. These results argue against depletion by either stellar winds, diffusion or rotational mixing. Therefore the Li observed in Pop II stars provides a reliable estimate of the baryonic density. A more detailed discussion can be found in Bonifacio & Molaro (1996).

1. Introduction

The primordial nature of the Li observed in Pop II stars rests on the existence of the Spite plateau, i.e. constant Li abundance for dwarfs with $T_{\text{eff}} > 5700$ K and $[\text{Fe}/\text{H}] < -1.5$. Recently, some authors have claimed the existence of trends of Li abundance both with T_{eff} and $[\text{Fe}/\text{H}]$, and intrinsic dispersion on the plateau (Deliyannis et al 1993, Norris et al 1994, Thorburn 1994, Ryan et al 1996). In addition, one star in M92 has been found with $[\text{Li}] = 2.5$, which is well above the plateau value (Deliyannis et al 1995). These results would argue in favour of a depletion of Li in the atmospheres of Pop II stars, weakening its cosmological significance. The existence of the Spite plateau has been defended by Molaro et al (1995) and Spite et al (1996).

2. A Selected Sample for Lithium

T_{eff} is the major source of error in the Li abundance determination and a precise determination of T_{eff} is necessary in order to discuss possible trends or dispersion on the plateau. The best method to determine T_{eff} , short of a direct measure of the angular diameter, is the IRFM (Blackwell et al 1990). Here we revise the Li abundance for 64 Pop II stars, which are about 2/3 of the Pop II stars observed for Li, using new IRFM T_{eff} obtained by Alonso et al (1996). Gravities have been recomputed for all the stars and results are shown in Fig. 1. The exclusion of the few possible subgiants from the sample does not alter significantly the results presented in this paper. The Li EWs have been

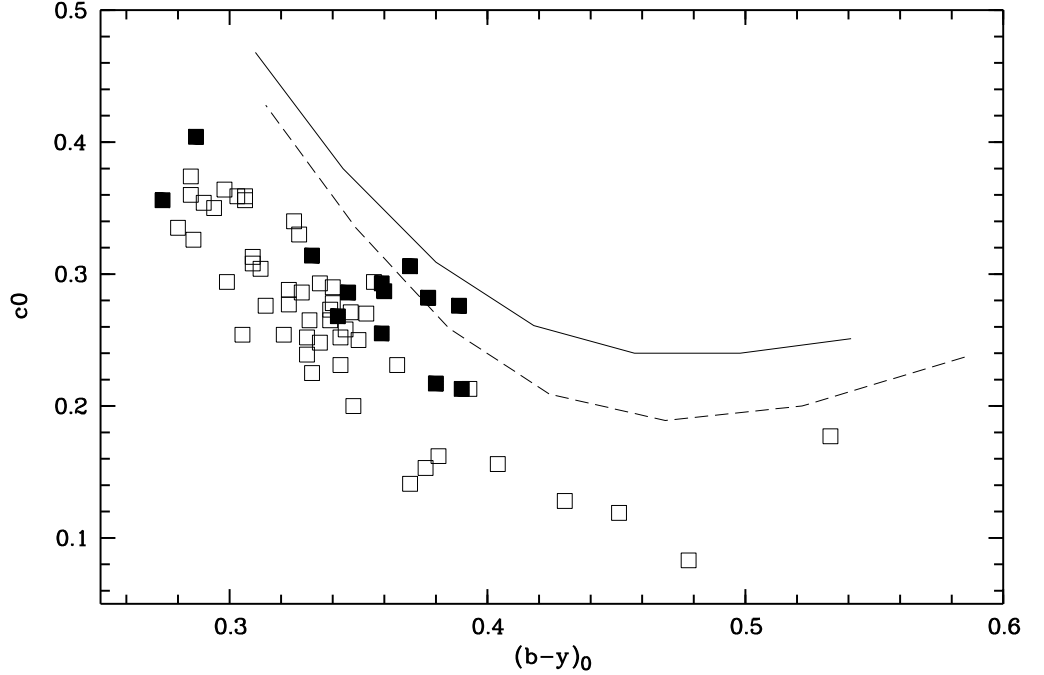


Figure 1. The $c0, (b - y)_0$ diagram for our sample of Pop II stars. The solid line represents the locus of points with $\log g = 3.5$ for $[\text{Fe}/\text{H}] = -1.5$. The dashed line is the same but for $[\text{Fe}/\text{H}] = -3.0$. The region above these lines is populated by subgiants and giants. The filled squares are the stars with $[\text{Fe}/\text{H}] > -1.5$ while the open squares are stars with $[\text{Fe}/\text{H}] \leq -1.5$.

taken from the literature. For multiple measurements we adopted the weighted average. The errors have been taken from the original papers, when available or estimated according the Ryan et al (1996) prescriptions.

2.1. Models

Abundances have been derived computing new atmospheric models by using the ATLAS9 code of Kurucz with enhanced α -elements and without the overshooting option. The theoretical EWs have been computed by direct integration of synthetic spectra computed with the SYNTHE code, thus taking into account the doublet structure of the Li 670.7 nm line. The models used are important in Li analysis, and systematic differences among different authors of the order of 0.1 dex have been ascribed to different assumptions in the model computations (Molaro et al 1995) .

3. Results

The results, based on 41 plateau stars with $T_{\text{eff}} > 5700$ and $[\text{Fe}/\text{H}] \leq -1.5$, give a weighted mean value $[\text{Li}] = 2.20 \pm 0.016$ ($[\text{Li}] = \log(\text{Li}/\text{H}) + 12$). In good agreement with the value of $[\text{Li}] = 2.21 \pm 0.013$ of Molaro et al (1995), who

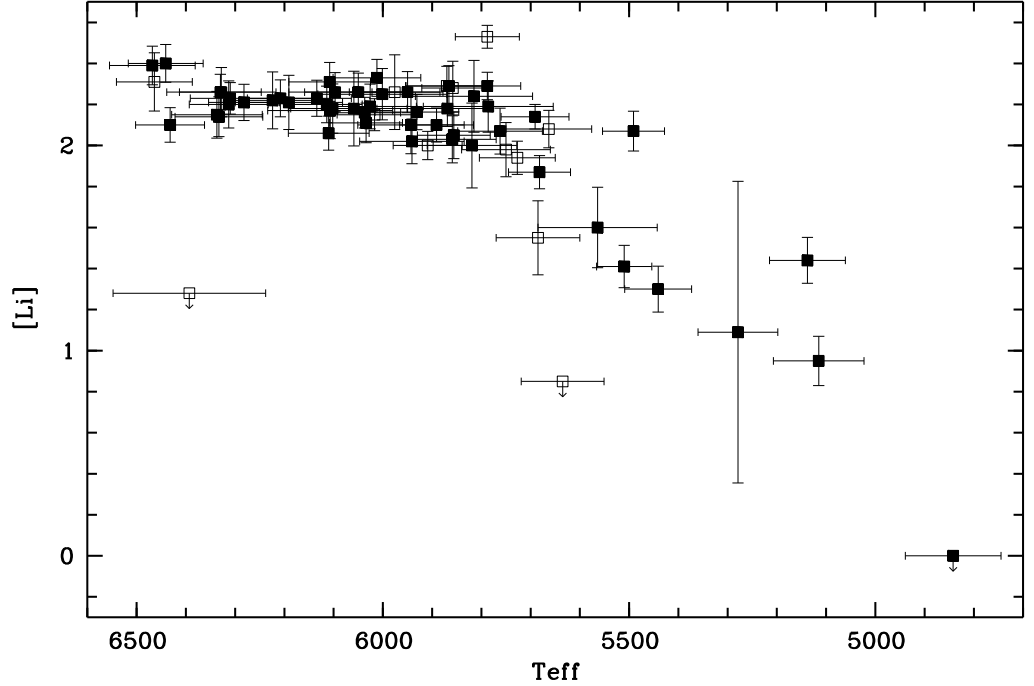


Figure 2. The $-[\text{Li}]$ T_{eff} diagram for our sample of stars. The filled squares are stars with $[\text{Fe}/\text{H}] \leq -1.5$, while the open squares are those with $[\text{Fe}/\text{H}] > -1.5$. Upper limits are shown with downward arrows.

used spectroscopically derived temperatures. The standard error is compatible with the estimated observational errors (0.11 ± 0.03 dex) showing no evidence for intrinsic dispersion. No trends of $[\text{Li}]$ with $[\text{Fe}/\text{H}]$ are found over the range $-3.5 \leq [\text{Fe}/\text{H}] < -1.5$. A tiny trend with T_{eff} is detected at 1σ level. Our current best estimate, based on a bivariate fit is:

$$[\text{Li}] = 1.146 + 0.033(\pm 0.046) \times [\text{Fe}/\text{H}] + 0.018(\pm 0.011) \times T_{\text{eff}}/100$$

Our slope with T_{eff} is smaller by about a factor of two than that found by Norris et al (1994), Thorburn (1994) and Ryan et al (1996) and is compatible with the mild depletion predicted in this temperature range, by the standard models of Deliyannis et al (1990).

The absence of a downturn in Li abundance at the hottest edge of the plateau and the absence of dispersion on the plateau itself argue strongly against significant depletion by diffusion or rotational mixing. (Vauclair 1988, Pinsonneault et al 1992). The absence of a significant slope with T_{eff} and the absence of intrinsic dispersion rule out stellar winds as possible depletion mechanisms (Vauclair and Charbonnel 1995). All depletion mechanisms predict features that are present in the observed data. Our results strongly support the view that the observed $[\text{Li}]$ in Pop II stars coincides with the primordial value.

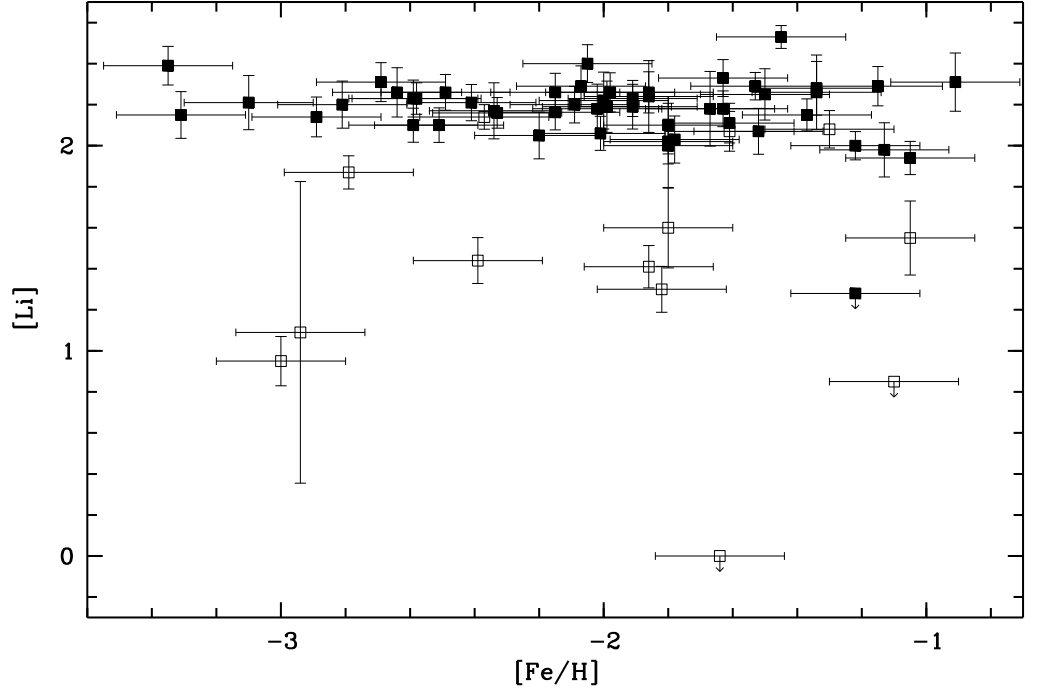


Figure 3. The $[\text{Li}] - [\text{Fe}/\text{H}]$ diagram for our sample of stars. The filled squares are stars with $T_{\text{eff}} > 5700$ K, while the open squares are those with $T_{\text{eff}} \leq 5700$ K. Upper limits are shown as downward arrows.

4. Primordial Li

A plausible estimate for Li_p can be deduced from the weighted mean of plateau stars after the small trend with T_{eff} , predicted by the standard models of Deliyannis et al (1990), is accounted for; thus leading to

$$[\text{Li}]_p = 2.240 \pm 0.016_{1\sigma} \pm 0.05_{\text{sys}}$$

The systematic error follows from the error on the zero point of the T_{eff} scale. This corresponds to two possible values for $\eta = n_B/n_\gamma$. With $\eta_{10} = 10^{10}\eta$:

$$\eta_{10} = 1.7^{+0.6}_{-0.3} \quad \text{or} \quad \eta_{10} = 3.9^{+0.9}_{-1.0}$$

But considering the full errors both in the Li abundance and in the theoretical BBN predictions the minimum of the Li SBBN prediction is allowed and the two intervals merge. Our low η is in agreement with that obtained from high deuterium values, $\text{D}/\text{H} \approx 10^{-4}$ (Songaila et al 1994, Carswell et al 1996, Wampler et al 1996, Rugers and Hogan 1996) and with that obtained from primordial helium $Y_p = 0.228 \pm 0.005$ (Pagel et al 1992). Our high η is more consistent with the $Y_p = 0.241 \pm 0.003$ (Izotov et al 1994) who use revised neutral helium recombination coefficients, but it remains inconsistent with the values from the low $\text{D}/\text{H} = 2 \times 10^{-5}$ observed in high redshift absorption systems (Tytler Fan and Burles 1996, Burles and Tytler 1996). The consistency between the low

D/H value and Li requires a 0.5 dex of depletion in Li which is not supported by the present analysis. The two intercepts on the Li theoretical curve corresponds to two preferred values for the baryon density

$$\Omega_B h^2 = 0.0063^{+0.0022}_{-0.0011} \quad or \quad \Omega_B h^2 = 0.0146^{+0.0033}_{-0.0037}$$

where the Hubble parameter is $H_0 = 100h \text{ Kms}^{-1}\text{Mpc}^{-1}$. Considering that $\Omega_{LUM} = 0.004 + 0.0007h^{-3/2}$ (Persic and Salucci 1996), over the entire range of H_0 we have $\Omega_B \geq \Omega_{LUM}$ suggesting the presence of dark baryons. The low value for η when combined with the high baryon fraction from X-ray of rich clusters leads to a total mass $\Omega_M \leq 0.2$, and to the so called "X-ray Cluster Baryon Catastrophe".

References

- Alonso A., Arribas S., Martinez-Roger C. 1996, AAS, 117, 227
Blackwell D. E., Petford A. D., Arribas S., Haddock D. J., Selby M. J. 1990, AA, 232, 396
Bonifacio P., Molaro P. 1996, MNRAS, submitted
Burles S., Tytler D. 1996, Sci, submitted, astro-ph 9603069
Carswell R. F., Rauch M., Weymann R. J., Cooke A., J., Webb, J. K. 1994, MNRAS, 1994, 268 L1
Carswell R. F., et al 1996, MNRAS, 278, 506
Deliyannis C. P., Boesgaard A., King J. R. 1995, ApJ, 452 L13
Deliyannis C. P., Demarque P., Kawaler S. D. 1990, ApJS, 73 21
Deliyannis C. P., Pinsonneault M. H., Duncan, D. K. 1993, ApJ, 414 740
Hata N., Steigman G., Bludman S., Langacker P. 1996, astro-ph 9603087
Izotov Y., I., Thuan T., X., Lipovetsky 1994, ApJ, 435, 647
Molaro P., Primas, F., Bonifacio, P. 1995, AA, 295, L47
Norris J. E., Ryan, S. G., Stringfellow G., S. 1994, ApJ, 423, 386
Pagel B. E. J., Simonson E. A., Terlevich R. J., Edmunds M. G. 1992, MNRAS, 255, 325
Persic M., and Salucci P. 1996, MNRAS, submitted
Pinsonneault M. H., Deliyannis, C., P., Demarque, P. 1992, ApJS, 78, 181
Ryan S. G., Beers, T. C., Deliyannis C. P., Thorburn J. A. 1996, ApJ, 458, 543
Rugers M., and Hogan C., J. 1996, ApJ, 259, L1
Songaila A., Cowie L.L., Hogan C.J., Rugers M. 1994, Nat, 368 599
Spite M., Francois P., Spite, F., Nissen P., E. 1996, AA, 307 172
Thorburn J. A 1994, ApJ, 421, 318
Tytler D., Fan X.M, Burles S. 1996, Nat, 381, 207
Vauclair S., Charbonnel C. 1995, AA, 295 715
Vauclair S. 1988, ApJ, 335 971
Wampler et al 1996, AA, in press, astro-ph 9512084